BOOK REVIEW

Edwin Clarke and Kenneth Dewhurst: *An Illustrated History of Brain Function.* Berkeley and Los Angeles, University of California Press, 1972. 154 pp. Illustrated. $14.00.

SELDOM does a book cross one's desk which is of such absorbing interest, first for its historical content and literary presentation and second for its great esthetic value both in artistic content and in technical format. On paper of excellent grade, with the print arranged in columns easy to read, profusely and yet selectively illustrated, and of free-flowing literary style, this brief volume deserves a place in the libraries of all those whose interests are even remotely connected with cerebral function.

The main aim of the authors is the portrayal of the idea of localization of brain function. A supplementary aim, admirably achieved, is the history of illustration. The story is that of the anatomist and the research worker collaborating with the artist to clarify ideas for their readier acceptance by those seeking to learn. Often credit for a discovery goes not to the man who makes it but rather to the man who convinces his colleagues of its significance in their daily work. For those interested in the history of anatomical illustration, several good reference sources are given, including references to specific organs.

Although the authors deal with the period of antiquity, their discussion has little to offer on the subject except for the Alexandrian period, the story of which was preserved for us by the scholars who fled Byzantium after the fall of Constantinople. Hippocrates wrote with an awareness that the brain was involved in perceptive intellectual and sensory functions, but he did not formulate any specific concept of brain function. Of even greater antiquity is the Edwin Smith Papyrus. In this document the ancient Egyptians mention briefly what can be interpreted as the convolutions of the brain.

The authors devote much attention to the controversy, which began in antiquity and lasted through the middle ages, and over the question of whether the seat of the soul was in the heart or in the brain. For those who chose the brain, the fourth ventricle had a favorite position. This position was shared by the "rete mirabile," wherein the vital spirits were converted into animal spirits.

Of these elements the ventricles figured prominently in the "cell" doctrine of brain function, so named by two of the early church fathers, Nemesius, Bishop of Emesia, and St. Augustine. The cell doctrine became the essential focus in the study of cerebral function during the middle ages. Many complicated systems were developed, all on a philosophical rather than an anatomical basis.

According to one of these systems, sensations created images in the first cell or ventricle. These were manipulated in cell two, where reasoning was located; whatever was left over was stored in cell three (memory). Even now we are still trying to understand the manner in which external stimuli are perceived, sorted, coded, stored, decoded, and recalled. We speak in a more sophisticated manner of the role of the anterior temporal lobes in the mnemonic process and the severe deficit which is observed when both temporal tips are ablated—the Klüver-Bucy syndrome—but I doubt that we are any closer to the answer than our predecessors were in the middle ages. Our catalogue of brain function has been enlarged with thalamic relays and specific memory banks where function is localized, but we are no closer to an answer. The same proliferation occurred with the cell theory toward the end of the 15th century, when more and more subdivisions were devised within the ventricles to localize specific functions and mental attributes.

As the Renaissance dawned, the only real improvement was in the art work. There was as yet no real representation of the brain and its convolutions, even though one of DaVinci's drawings shows the layers of the scalp and dura and then the ventricles of the brain, drawn in the classical pattern of interconnecting systems in a straight line. This period did bring a new refinement of the cell doctrine, the dynamic concept in which there was a flow of information from one ventricle or cell to another. The regulator of flow from one ventricle to the other was called the vermis, which corresponds to the choroid plexus. The concept of a time element in the connection of thought processes was introduced by Albertus Magnus in his *Parvulus Philosophiae Naturalis* (1473). Resemblance to the anatomical ventricles first appears in Reisch's portrayal (1503) of three cells or ventricles. There is even a suggestion of a convolutional pattern of the brain in his drawing, which was good enough to be plagiarized until well into the 19th century.

The authors include a brief history of the pictorial representation of the eye and its projections. In a 13th-century Syrian treatise on ophthalmology there is a drawing, probably dating back to the 11th century, which clearly depicts the decussation of the optic chiasm. Medieval representations were cruder, did not show the chiasm, and were involved with speculative connections in the ventricles. However, one drawing, dated 1367, shows a crossing of the optic projections to the opposite side of the brain, but not a crossing chiasm.

The Renaissance brought a more skeptical approach to learning and the cell doctrine began to lose ground, although some authors continued to use that theory. Its tenacity is exhibited by the authors in an illustration of the Zodiac Man from a book on surgery and anatomy by Francisco Suarez (1548-1617), published in Madrid as late as 1728. The first transitional step was the rediscovery of the ventricular system, previously described by the Alexandrian anatomists and by Galen, and then lost when theology and armchair philosophy supplanted observation.

Consonant with the secondary theme of this book—the role of the artist in the advancement of anatomy—we find the quality of accurate observation in the great artist, whether a poet like Homer or a sculptor like Praxiteles, in Leonardo DaVinci's wax cast of the ventricles of the ox. The fact that Leonardo superimposed medieval physiological concepts on the new Renaissance anatomy detracts nothing from his leadership in the transitional period.

Although Leonardo did not seem to have much influence on contemporary anatomical studies, the changed atmosphere was evident, as some 20 years after Leonardo's wax casts, Berengario DaCarpi was producing in his *Isagoge Breves* (1522, second edition, 1523) anatomical illustrations in which the ventricles were depicted with recognizable accuracy in anatomical terms and without the medieval designations of the cell doctrine. Henceforth, this medieval doctrine was eliminated irrevocably from reputable textbooks of anatomy.

The *De Fabrica* (1543) established Vesalius as the greatest of the Renaissance anatomists. He was taught the cell doctrine but rejected it. His depiction of the ventricles demonstrated the increasing accuracy that was being achieved by anatomical dissection as an instructional method. One faithfully drawn illustration of the brain shows the ventricles to be enlarged and the sulci to be widened, obviously a case of cortical atrophy and hydrocephalus *ex vacuo*. Vesalius himself was satisfied to revert to the ancient Greek notion that the ventricles were the repository of animal spirits which were responsible for the motor and sensory activity of the body. Clearly, physiological localization in the brain was to lag far behind the anatomical description of that structure.

Even so accurate an observer as Vesalius was rather schematic in his representation of the convolutions of the brain, for while gyri are already drawn, they are treated casually and without consistent pattern. It remained for the anatomists of the 19th century to delineate the convolutions accurately and not as "coils of small gut."

Another traditional concept which suffered during the Renaissance was the rete mirable, that network of vessels at the base of the brain responsible for converting vital spirits into animal spirits. This remnant of Galenic anatomy was described in the brain of the ox, but it is not known to be present in man or monkey. So firm was the traditional concept, however, that Vesalius, as great an anatomist as he was, described the rete mirable in his earlier works. Later he was astonished at his own credulity and denied its existence explicitly in the *De Fabrica*. As late as 1664 Thomas Willis found it necessary to discuss the rete mirable in his renowned book on the brain. Willis was considering the comparative anatomy and did indicate that the rete was present in some animals but not in man. He recognized that in some human cases a resemblance to the rete was evident, a fact confirmed in the current arteriographic literature.

The circle of arteries at the base of the brain was depicted by Vesling in his *Syntagma Anatomicum* (1647 ed.) 17 years before it was described by the Willis for whom it became known as the circle of Willis. This representation is complete except for the anterior communicating artery, but a more serious error is the representation of the small branches from this circle like so many parts of a feather duster, labeled the rete mirable—another example of how hard it is for some terms to die.

Although the external portion of the brain would seem to be the most obvious place to start an accurate description of that organ, it is surprising how inaccurate the depiction of the convolutions was during the 16th century. The convolutions were described as fleecy clouds or coils of intestine, a casual treatment by the artist that perhaps revealed the lack of functional importance accorded that portion of the brain by the anatomist. The ventricular remained the important system.

With the advent of the 17th century there began a new interest in concepts of brain function and with it there appeared to be an increasing accuracy in the drawings of the brain. Descartes developed a mechanistic hypothesis of cerebral function. He was the first to develop a concept of afferent and efferent components of a reflex. Descartes' drawing of the brain and its convolutions in his book *De Homine* (1662) is quite acceptable by contemporary standards. The seat of animal spirits was placed in the pineal by Descartes. The next step was taken by Willis in his *Cerebri Anatome* (1664), which ended ventricular localization and ascribed functions to parts of the brain: e.g., incoming senses to the corpus striatum, imagination to the corpus callosum, and memory to the cortex. Sylvius suggested the cerebellum rather than the rete mirable or the ventricles as the repository of animal spirits or psyche.

Among the famous artists of that period, Rembrandt in his drawing Anatomy Lesson of Dr. Deyman (1656) depicts in that portion of the brain which is visible a rather acceptable representation of the convolutions. Christopher Wren did many of the illustrations in Willis' books.

Among the most notable anatomists of the 18th century was Soemmerring, whose drawing of the brain in sagittal section was the best to date. Vicq d'Azyr, a name familiar to neurologists, drew the convolutions of the brain with more concern for their size than their detailed pattern. This interest in the cortex took on new dimensions with the discovery of the microscope, and Leeuwenhoek, Malphighi, and Ruysch were all interested in examining the cerebral cortex with this new instrument.

At the beginning of the 19th century interest in the function of the cortex was accelerated and led to the new "science" of phrenology. The effect of the work of Gall and Spurzheim was to spur efforts in functional localization in the brain and its convolutions. Contemporary thought and philosophy were ripe to accept their theory, and popular interest in this study developed phrenology into a cult. It might be said that phrenology pushed the science of neurophysiology in the right direction for the wrong reason. Gall's discoveries in neuroanatomy were of great interest yet were overshadowed by the stigma of phrenology. His drawings of the gyri and sulci were both faithful to nature and artistically meritorious.

Phrenology was not without its opponents, chief among whom was Flourens who performed stimulation experiments in 1824 and focal extirpation of the brain in animals. He proved that there was localization in various parts of the brain, but he believed that intellectual perceptual functions were represented diffusely throughout the hemispheres. In opposition to Flourens' theory of equipotentiality, Fritsch and Hitzig demonstrated, in 1870, the excitability of the cortex and its localized motor functions. Earlier, clinicians such as Broca and Hughlings Jackson had demonstrated precise representation in the cortex on the basis of clinical and pathological data.

In 1873 David Ferrier carried out animal experiments at the West Riding Lunatic Asylum to test the ideas of Jackson regarding his concepts of focal epilepsy in precise localization in the cerebral cortex. He confirmed the work of Hughlings Jackson, and then went on to extend the work of Fritsch and Hitzig, using many animal species. He began the process of mapping the cortex, particularly with regard to motor points. This work was then carried on more extensively by Victor Horsley, Charles Sherrington in England, Charles K. Mills, Charles H. Frazier, and Harvey Cushing in this country, and by Fedor Krause in Berlin.

The cortical localizers found an opposing faction developing and espousing the "global" concept based on the theory of cerebral equipotentiality, which refers to the ability of any intact cortical area to execute the function of other parts of the cortex. The main exponent of cerebral equipotentiality and leader of the antilocalizers was F. L. Goltz of Strassburg.

Once again the anatomist entered the picture of localizing function in the cerebral cortex. Theodore Meynert was the pioneer in relating regional structural differences in the cerebral cortex to their functions (1867-1868). He used the technique of myelogenesis based upon the fact that function is possible only when myelinization is complete. His studies of function and their localization were based upon observations of the appearance of myelinization in the subcortical white matter of the developing human fetus and infant.

Architechtonics, which is the microscopical study of the appearance of cells and fibers, was the next fruitful area of cortical localization. It was Walter Campbell of Australia and Korbinian Brodmann of Germany who pioneered in this exacting field of research. The Vogts expanded this cortical localization to a point where there was considerable confusion, but the work of von Economo, published in 1925 and based upon Brodmann's work, helped to dissipate some of the confusion resulting from the plethora of cortical areas established by the Vogts.

From the standpoint of human cortical physiology, the work of O. Foerster of Berlin is of particular importance, as in 1924 this worker began his stimulation experiments on the human cortex. Using the diagram that the Vogts had provided for the monkey, he tried to outline the same degree of localization in the human. His numbers followed closely those of Brodmann. His studies excited the interest and imagination of Wilder Penfield, who worked with him in 1928 and thus began a lifelong interest in cortical localization.

Penfield and his associates at the Montreal Neurological Institute and Fulton and his associates at the Yale Laboratory of Physiology made large contributions and ushered in the modern era of cortical localization. Despite the precision of their localizations, the work was not without its detractors. Among them was Henry Head, who called the graphic summaries of cortical localization the work of "diagram makers." Thus, concurrently we see the re-emergence of the advocates of equipotentiality of the cortex. As stated earlier, this was first propounded by Goltz. Carl Lashley added the principle of mass action and modified his concept of total equipotentiality to one of areal equipotentiality. The greatest supporters of the concept of cortical equipotentiality have been the behavioral psychologists and Pavlovian physiologists, while those working in the clinical neurological fields have been more inclined to support the theories of precise cortical localization. Certainly, the representation of the sensory and motor homunculus by Penfield and Boldrey in 1937 and that of Penfield and Rasmussen in 1957 have been standard guidelines for neurologists and neurosurgeons.

One of the objections of precise localization is that it does not take into account the tremendous integrative action of the brain, and in this respect even the clinical neurologists recognize that such concepts as those of body scheme, perceptual judgment, visual and auditory recollection, motor and sensory elaboration, spatial perceptual ability, and concepts of short-term and long-term memory may have areal predominance, but not the type of precise cortical localization seen with motor points. However, it should be pointed out that these concepts all represent complex integrative mental functions which in no way resemble the precise localization of motor points for individual muscles which neurophysiologists have demonstrated by means of cortical stimulation. One would have to conclude that in its sphere each concept—areal equipotentiality and precise localization—has its place.

A further concept of integration of brain function was represented by Magoun in 1963, when he discussed the ascending reticular system in the core of the brain stem. This system receives collaterals from multiple afferent pathways in the brain stem and then projects to multiple cortical areas. The reticular formation affects the waking and sleeping state and in this way directly influences the integration of cortical function.

Areal representation dates back to the days of the early clinical neurologists who described syndromes associated with lesions in various anatomical lobes of the brain. Hughlings Jackson recognized the frontal lobes as an area of intellectual capacity, but the concept of the frontal lobes as the repository of intellectual functions has been abandoned because it has been clearly demonstrated that while people with tumors of the frontal lobe have bizarre behavior, those with lesions in the parietal lobe have greater intellectual dysfunction. With respect to the parietal lobes, MacDonald Critchley has surveyed the complexity of parietal lobe function in his excellent monograph. He has especially elaborated upon concepts of the body scheme and spatial perceptual ability. More recently, interest in temporal lobe function and psychiatric disturbances has been elucidated by Scoville and Milner and by McLean.

Passing from the representation of function in specific lobes of the brain, one may proceed to the consideration of asymmetrical representation in the hemispheres. The early impetus in this direction was developed from Broca's rule that righthandedness was associated with cortical representation of language in the left hemisphere. Since that time there has been a considerable expansion in the study of the aphasias and a wide bibliography has been accumulated on the various types of aphasia and the hemispheral representation of speech.

Finally, in the most modern of times there have been developed a number of ancillary aids to the localization of lesions of the brain; these include air studies, brain scans, and arteriography. The history of cerebral localization is pretty well borne out by the correlations provided by these more recent and more accurate means of localization, even though these diagnostic studies have shown that experience is not infallible.

There has been little, if anything, to criticize in the delightful monograph that has been prepared by Doctors Clarke and Dewhurst. Perhaps a little more might have been offered on the medical history of the Near East and the Far East, since the book will prove to be a highly specialized reference source for some time to come, but even in Cushing's amazing medical historical collection I can recall only a few items from Persia and China, so this lapse is quite understandable. One can recommend this book as both interestingly entertaining and scientifically informative.

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